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Mini Review

Predicting the microbial safety of irrigation water and fresh produce: A collaborative approach

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Outbreak of food borne illnesses as a result of consumption of fresh vegetables and fruits is occurring regularly. In USA for example, it has become business as usual to hear and read about fresh produce recalls. Although, the increase has been attributed to many factors it is however more important to find solution to the problem. An effective solution will be a proactive approach such as prediction and forecasting which are not new in the field of meteorology. For many years now, meteorologists have been predicting the weather. It is indeed high time that food scientists in collaboration with other professionals found out dependable and realistic methods to predict the presence of pathogens in irrigation water and fresh produce. In this review, several prediction tools such as factor analysis, artificial neural network, support vector machine, logistic regression analysis, partial least square and 'nanosensing' were discussed. The problem of produce safety may in fact be solved when food scientist collaborate with I.T professionals, biotechnologists and others.

Key words: *Listeria monocytogenes,* neural network, nanosensing, partial least squares, food safety.

INTRODUCTION

The rate of food borne disease outbreaks caused by produce contamination has increased from 0.7% in the 1970s to 13% between 1990 and 2005 (Ailes et al., 2008). Recently (May-June 2011), consumption of cucumber tainted with *Escherichia coli* caused the death of 14 people in Germany and other European countries (Badeniyi, 2011; ISN, 2011).

The increase is attributed to improved diagnostic methods, food borne disease surveillance systems enhancement and also to increase in the consumption of fresh fruit and vegetables (Ailes et al., 2008). There are ample avenues for produce to become contaminated during production and afterwards (Beuchat and Ryu, 1997; Beuchat, 2002, 2006). According to Johnston et al. (2006) contamination takes place at different stages of produce's growth, harvest, packing and distribution. Contaminated irrigation water sources have been reported as a major way by which fruits and vegetables become contaminated with bacteria pathogens (Ibenyassine et al., 2006).

Different human pathogenes have been recovered from irrigation water and produce by several workers. The result of sampling done to determine the microbiological quality of irrigation water and vegetables in South Africa showed high prevalence of *Listeria monocytogenes, Salmonella* and intestinal *Enterococcus* (Ijabadeniyi et al., 2009). Also, Steel et al. (2005) carried out a survey on 500 irrigation water samples used for production of fruit and vegetables in Canada and found about 25% of the water samples contaminated with faecal *E. coli* and faecal *Streptococci*. River water used for both human and animal waste disposal poses a health risk of

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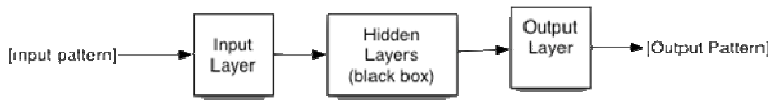

Figure 1. A typical neural network (Heaton, 2010).

contamination with *Salmonella* and *Listeria* when such river waters are used for irrigation of produce (Johnson et al., 1997; Combarro et al., 1997). Combarro et al. (1997) isolated different *Listeria* species from river water in Spain. The specie most isolated was *L. monocytogenes,* followed by *Listeria seeligeri*, *Listeria velshimeri and Listeria ivanovii* being the least commonly isolated. Similarly, Geuenich et al. (1985) and Bernagozz et al. (1994) recovered approximately 73 and 93% of *L. monocytogenes* respectively from the total *Listeria* isolates from river water.

Ijabadeniyi et al. (2011) used stepwise logistic regression analysis to predict the presence of bacterial pathogens, that is, *Salmonella* spp, *L. monocytogenes* and intestinal *Enterococcus* in irrigation water and vegetables. It was evident from their work that faecal coliform, COD, and turbidity could be used to predict the presence of *Salmonella* sp, *L. monocytogenes and* intestinal *Enterococcus* respectively in irrigation water. The workers also found that aerobic colony count (ACC) could be used to predict the presence of the pathogens vegetables.

Determination of the presence of all these pathogens in irrigation water and vegetables could be costly and also time consuming. It is important to use different statistical and computational modelling tools that determine variables which measured faster.

In this review such prediction tools e.g factor analysis, artificial neural network, support vector machine, logistic regression analysis and partial least square were discussed. Other things that were also covered are the use of nanosensing for prediction of food safety and the importance of collaboration in solving food safety problems.

TOOLS FOR PREDICTION

Factor analysis

Factor analysis is a statistical analysis tool. It is however different from the t test or ANOVA which test differences between two groups of subjects. According to Pett et al. (2003), factor analysis represents a complex array of structure –analyzing procedures used to identify the interrelationship among a large set of observed variables. Breaking down factor analysis definition, a factor is a linear combination or cluster of related observed variables that represents a specific underlying dimension of a construction separate from the other factors included in the solution (Tabachnick and Fidell, 2001). With the help of factor analysis, structural interrelationships among diverse variables can be summarized and described in a concise and understandable manner (Gorsuch, 1983).

Although there is little or no reported work on the use of factor analysis technique for prediction of food or produce safety, Leske (1991) used it to identify five underlying dimensions or factors related to the critical care family needs inventory (CCFNI), an instrument designed to assess the needs of family members of the critically ill. The technique showed CCFNI factors which are needs for support, comfort, information, proximity and assurance. This statistical tool also has potential for prediction and forecasting of produce safety.

Artificial neural network (ANN)

Artificial neural network is one of the few computational intelligence tools. They are preferred above statistical tools because they can be used to solve extremely challenging problems faster (Eberhart and Shi, 2007). ANN was developed and patterned after the massively parallel structure of the brain hence there are some basic similarities between biological neural networks and artificial neural networks (Heaton, 2010). It processes highly interconnected analogous data sets into simple individual processing elements (PEs).

Figure 1 shows a typical neural network which processes information like the brain does it (Stergiou and Siganos, 2011). The input layer consists of the analogous processing elements (or neurons). There is a weighted connection from every input layer to every hidden layer, and there is a weighted connection from hidden layers to every output layer (Eberhart and Shi, 2007). Neural networks can perform diverse kinds of operations such as classification, pattern matching, pattern completion, optimization, simulation (Eberhart and Shi, 2007) and most importantly they can be used for prediction of safety of foods. Although, neural networks cannot perform miracles they can however produce amazing results if used sensibly (Stergiou and Siganos, 2011).

Support vector machine

This tool is able to predict input data that are similar or in the same class from a set of many in put data. Support vector machine models are however similar to neural networks. A model using a sigmoid kernel function is equivalent to a two-layer, perception neural network (DTREG, 2011).

Logistic regression

Logistic regression (LR) analysis is a mathematical and statistical modeling approach that is able to determine the relationship between predictor variables (Kleinbaum et al., 2008). LA is very useful in epidemiological studies. For example, LR has been used to predict the risk of an individual developing a disease (Kleinbaum et al., 2008). LR is also becoming very relevant in food safety. Ailes et al. (2008) used this model to confirm that microbial concentrations on fresh produce are predicted by post-harvest processing, importation and the season. Also, the absence of some indicators in water was significant to predict its safety through the logistic regression model (Horman et al., 2004). Also with the same model, Ijabadeniyi et al. (2011) showed that faecal coliforms and coliforms can be used to indicate a high probability of *Salmonella* presence in water and they may be used as risk parameters. It also showed that there is a relationship between the physiochemical properties of water, that is, COD, turbidity and certain bacterial pathogens, that is, *L. monocytogenes* and intestinal *Enterococcus*. The logistic regression analysis may therefore be used as a tool for predictive microbiology model which has an immediate practical application to predict microbial produce safety and quality, and provide quantitative understanding of the microbial ecology of irrigation water and produce (Ross et al., 2000).

Partial least square

Partial least squares (PLS) which was developed in the 60's by Herman Wold is an effective useful tool for prediction. One advantage of PLS is that it can be used with very many variable factors (Tobias, 2011). Abdi (2011) also reported that it is suitable to use it when a set of dependent variables are to be predicted from a very large set of independent variables (that is, predictors). This computational statistical tool will most likely be applicable in prediction of produce safety. According to Esposito et al. (2010), PLS is useful in several subject areas including marketing. However, PLS was first applied in chemometrics (computational chemistry) because that was the field of the initiator son's (Svante Herman) and it has also been popularly used in sensory evaluation (Geladi and Kowalski, 1986; Martens and Naes, 1989).

Nanosensing

The addition of nanoparticles to food directly or indirectly through the packaging material may be an effective way to predict the safety of food in the nearest future. A nanosensor that quickly sends a signal when it detects a bacterial pathogen in the food may be added to food. This type of sensor has been used to find out the site of tumors within body. According to Foster (2006), cadmium selenide quantum dots were able to easily uncover tumor or cancer cell because of their fluorescence properties. The only disadvantage is that cadmium selenide is toxic to human and it is reported that scientists are looking at developing less toxic materials. It is this type of less toxic nanomaterials that will be used in prediction of food safety.

Food pathogens will be detected with the aid of nanosensors that had been placed directly into the packaging material serving as 'electronic tongue' or noses by detecting chemicals release during food contamination and spoilage (Bhattacharya et al., 2007). According to Lilie and Cantini (2011), nanosenser will help to recover even just one *E. coli* bacterium located in ground beef. Another advantage of nanosensor is that it can measure safety at real time and the procedures are quick, sensitive and less labour-intensive (Das et al., 2009).

Solving the problem of produce safety with a collaborative approach

Covey (2004), in his best seller book- The Seven Habits of Highly Effective People- emphasized the importance of synergy. According to him, effective people must learn to synergize. Synergy is not only important in the business world but it is also paramount in solving the challenges of produce safety.

According to Yiannas (2009), one of the four critical factors needed to make significant leaps in food safety is better collaboration. Because food safety has become a shared responsibility of all the stakeholders; regulators, academicians, consumers and industry professionals must therefore come together for a common goal which is getting a panacea to the problems of food safety (Yiannas, 2009).

Researchers have learnt the habit of working with other researchers in the same field, however, they must synergize better by working and collaborating with other researchers in a different field. Authors of this paper totally agree with the author of Food Safety Culture; Creating a Behavior –Based Food Safety Management System when he wrote "we need to learn from other disciplines such as medical, information technology, and biotechnology fields. I believe some of our greatest future food safety solutions may not even come from within the field of food safety".

Collaboration may be between a researcher who is an expert in statistical or computational intelligence, and the other who has collected a lot of data from a field experiment probably in the field of food safety.

Collaboration will allow the researchers to combine their strengths and do sophisticated statistical and computational analysis of the data from the field experiments (Wisegeek, 2011). This type of research is in particular necessary in Africa where output is low compared to other continents. It has the advantage of making research to be more likely funded. A recent report on worldwide scientific collaboration emphasized that collaboration is becoming an important indicator of competitiveness because it enhances research quality, improves its efficiency and effectiveness. Furthermore, it is also becoming increasingly necessary as budgets and research challenges grow (Pauw and van Zyl, 2011).

CONCLUSION

Statistical analytical and computer intelligence tools such as factor analysis, artificial neural network, support vector machine, logistic regression analysis and partial least square can be used to predict the microbial safety of fresh produce. Although, there is little or no report of their application in food safety, this may soon change as food scientists begin to realize their immense benefits and potentials. Furthermore, the use of nanotechnology and 'nanosensing' as a tool for prediction and forecasting of pathogens in irrigation water and on produce is of great interest. These tools will definitely produce positive results when employed in the atmosphere of collaboration.

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